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Introduction

Timothy F. Bresnahan and Robert J. Gordon

The value of an hour of human life has been immeasurably increased by the successive invention of electric urban transport followed by motor transport on an ever more extensive highway infrastructure; faster trains soon made obsolete by piston and then jet airplanes; primitive local telephone service followed by ever cheaper long-distance service, cellular phones, and spreading data links; a host of durable appliances that greatly reduced household drudgery; and generations of home-entertainment devices, from crackling radios to small, dim, black-and-white televisions to today's color television systems of startling size and clarity to compact-disc players with lifelike fidelity. As we write, this list is being augmented by the spread of multimedia personal computers and the imminent accessibility to many homes of huge amounts of information through CD-ROMs and the World Wide Web. The length of human life, as well as its quality, has likewise been increased by a host of new medical hardware, from x-ray magnetic resonance imaging machines, as well as by an array of pharmaceutical marvels, from penicillin to the latest antidepressants.

Clearly, new goods are at the heart of economic progress. But that realization is only the beginning of an understanding of the economics of new goods. The value created by new goods must somehow be converted into an exact quantitative measure if official data on inflation (like the Consumer Price Index) are to represent accurately the theoretical concept of a true "cost-of-living" index, and if official data are to capture the annual increase in output and productivity contributed by the invention of new goods, as well as by steady improvements in the quality of old goods.

The Economics of New Goods encompasses the history of invention and

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improvement, exploring the theory that converts the broad notion that new goods improve human welfare into specific, quantitative ideas about measurable improvements in welfare and presenting detailed case studies of the problems encountered in converting theory to practice. This introduction to the volume attempts to advance our understanding of economic innovation and the economics of new goods. In so doing, it places within a broader context the specific contributions within these covers, which include historical treatments of new goods and their diffusion over substantial periods of time, practical exercises in measurement addressed to recent and ongoing innovations, and the real-world methods of adjusting for quality change carried out in official statistical agencies.

Human Welfare, the Cost-of-Living Index, and the Consumer Price Index

Innovations are important if they make a difference in the way human beings live and work. Most people share a set of common values and goals and agree on what it means to realize these objectives more fully. People care about freedom; nourishment; shelter; mobility; the onerousness and duration of work; and the offsetting uplift from family, friends, and entertainment. New goods matter if they improve the quality of life along these lines and/or allow the current quality of life to be maintained at less expense.

The contribution of new goods to consumer welfare is inseparably linked to the concept of the true cost-of-living (COL) index and to the creation of aggregate measures of the price level and national output. The standard definition of a COL index is the ratio in two situations (usually two time periods) of the minimum expenditure required to achieve the same level of well-being. A meaningful consumer price index linked to the notion of consumer welfare should approximate the true COL index, and measures of the output of consumer goods (i.e., real consumption expenditure) should be calculated by deflating current-dollar consumer expenditure by the same consume price index. Yet difficulties in translating the theoretical notion of a COL index into an actual consumer price index are significant. What does "the same level of well-being" mean when products are replaced by new versions embodying different quality attributes? An even more profound difficulty is, what does "the same level of well-being" mean when entirely new products are introduced that were unavailable in the first time period?

The Sears Catalogue Experiment

Many of the new goods we discuss here have made a huge difference in human life, and their invention explains why almost any person living in an advanced economy today would be appalled by the suggestion that they be cast back two centuries and forced to live in an era lacking these goods. The many dimensions of sacrifice suggested by the thought experiment of being cast back

two centuries are represented by a more specific conceptual exercise that has been discussed frequently in the literature on price indexes and quality change. If you had one thousand dollars to spend, would you rather order from the first Sears, Roebuck & Co. catalogue of 1893 or from the final catalogue published a century later, in 1993? An entire century's worth of inflation makes your dollars worth much less than in 1893 according to official price indexes: in fact, less than one-tenth as much. Yet the newer catalogue offers a vast array of useful and attractive items not available or even imagined in 1893. The value of these changes is central to an understanding of how much richer society has become over time, in dimensions that are neglected by official measures of inflation.

However, the Sears catalogue exercise involves a subtlety, because most people would want to play the game both ways. They would prefer to spend their first two or three hundred dollars at 1893 prices: on steak at $0.50 per pound, on four-course restaurant meals at $1.29 apiece, or on men's work pants at $2.29 a pair. But they would want to spend their last few hundred dollars on videocassette recorders (VCRs), compact-disc players, and other wonders of modern life. And, going beyond the confines of the catalogue example, they would without question prefer to be treated for disease at today's hospital rather than at its 1893 equivalent. In contrast to official price indexes, which state that more than ten times the income is required to maintain a given standard of living today than in 1893, most people are likely to choose a much lower number—three, five, or seven times, but not more than ten times. This assessment restates the widespread belief, discussed further below, that the official U.S. Consumer Price Index (CPI) is biased upward to a significant degree.

The Sears catalogue example points to some of the difficulties in creating quantitative measures of economic progress. Some goods, particularly raw foodstuffs, have not changed appreciably and have undeniably increased in price manyfold. Yet in many other cases, inventions have greatly reduced the price of fulfilling a particular human need, as in the case of light, discussed in the first paper in this volume, and have also greatly expanded the quantity of the commodity that is available (at any price) to the average household.

The lightbulb example illustrates the power of really important new goods. Little more than a century ago, such activities as evening reading or entertaining were luxuries. A series of new goods, such as whale oil for lamps, gaslight, and then the electric lightbulb, rapidly lowered the costs of using artificial light, a commodity which is complementary to a wide variety of household and workplace activities. Thus, as artificial light grew cheaper, activities which had been economic only for short parts of the day spread to evening, activities confined to summer became year-round, and jobs became easier to perform.

The True COL Index and the CPI

Because of these complementarities, large changes in households' cost of light lowered the true COL index substantially. When artificial light gave

people their evenings, it added time to their day. Constraints which made evening time less valuable were removed. A properly calculated COL index should reflect this advance and measure how much better-off consumers are, taking into account all the adjustments consumers make to their new circumstances (Diewert 1990). Thus, the decrease in the COL caused by the electric lightbulb is not confined to the difference in cost between oil lamps and electricity. Instead, it captures as well the value of time saved by consumers in trimming wicks and cleaning lamps, and the value of time freed for them both to pursue leisure activities in the evening and to make more productive their work activities during winter early mornings and late afternoons.

The official CPI in the United States and in most other countries makes no attempt to quantify the value of new products and often introduces them into the index many years after their initial introduction into the marketplace and after the initial phase of quality improvement and cost reduction. Therefore, the CPI has been widely assumed to incorporate a substantial upward bias, that is, to overstate the rate of inflation.[1] Recently this issue has entered the policy debate over the U.S. federal budget deficit. Many federal benefits expenditures are indexed to the CPI, as are parts of the tax code. A reduction in the CPI growth rate of 1 percentage point, or use of an alternative index growing that much more slowly, would reduce the deficit by $634 billion cumulatively between 1996 and 2005 (see U.S. Congress 1995, fig. A-2). The interplay between the economics of new goods and the construction of official price indexes is a major theme of this book.

Major Inventions, Minor Inventions, and Continuous Improvement

Thomas Edison's invention of the lightbulb, Henry Ford's introduction of the Model T, Vladimir Zworykin's television picture tube, and the Wozniak-Jobs innovations in the Apple II computer are all viewed as landmark events, "macro inventions" in the language of Mokyr (1990). These and many other new goods represent an expansion of the productive economy's ability to meet human needs. People have always wanted to extend the hours of daylight, to travel, to be entertained; workplaces have always needed to write and to calculate. Yet these landmark examples point to a complex, ongoing process. With each of these innovations a whole new industry was founded, but that was not the end of the story. In each case there followed subsidiary innovations that created dramatic improvements in performance and quality at substantially lower cost. In each case there followed also the development of related industries, from electricity generation to truck transportation to television and cable broadcasting to computer software production. In each case there was a change in the way people lived and worked, as ever cheaper electricity made possible home appliances that reduced drudgery, as motor transport led to the growth

1. The CPI also is subject to other forms of bias, including traditional substitution bias, outlet-substitution bias, and functional form bias, that are beyond the scope of the present volume. For a recent review see Wynne and Sigalla (1996).

of suburbs and a dispersion of economic activity, as television shifted entertainment from vaudeville and movie theaters to the home, and as the personal computer made possible working at home and scores of new service industries. Lowering costs, improving quality and performance, setting off subsidiary innovation processes, and permitting whole new ways of living—these are all part of the new-goods process.

The Household Production Function

The lightbulb example illustrates the value of using the "household production function" approach, introduced by Becker (1965), among others. The basic idea is that the activities that directly produce consumer welfare are indirectly produced by combining household time and purchased market commodities. The introduction of a new good, the lightbulb, is usefully viewed as one of a series of technical advances which lower households' costs of an activity called "making light." The technical advances themselves are very different from one another and are totally unconnected to the daily activities of households. Oil lamps called for improvements in ships, the better to hunt whales. Gaslight called for improvements in mining. The lightbulb was part of Edison's whole cluster of electrical inventions. Its invention stimulated an enormous outpouring of subsidiary inventions in the production and distribution of electricity, which accompanied further improvements in the lightbulb itself. The overall effect of all these different technical advances was to permit changes in the way that households produced light. The resulting fall in the "price of light" was dramatic and hugely valued by every household, regardless of its members' occupations, social class, or level of income.

The scope of the impact of new goods is quite broad. Consider the problem of wearing clean clothing. A century ago, this called for a large commitment of time and money. Technical change in a variety of areas led to new goods which dramatically reduced this cost. Among these were the washer and dryer, classic household labor-saving devices. Together with innovations in materials such as wash-and-wear fabrics and inexpensive detergents, these inventions permitted substantial savings in the household time allocated to the drudgery of creating clean clothes, releasing much of that time for more pleasant activities. The substitution of machines and fabrics for household labor, however, represents only part of the improvement. It also lowers the marginal price of one output of household production, clean and colorful clothing. As a result, households substitute toward this output. Depending on the strength of this substitution, there may actually be little saving of labor. All of the benefits are consumed as higher-quality final consumption, the ultimate aim of household production.

Multiple Dimensions of Wants

When new goods, new kinds of goods, or whole new industries achieve marketplace success, we infer that they satisfy previously unmet, or at the least badly met, needs. The needs for transportation services now met by the auto-

mobile always existed, and in order to understand the value of the invention of the automobile, it helps to distinguish at least five attributes of transportation services: cost, speed, production of by-products, comfort, and flexibility in providing transportation at the chosen time and between the desired origin and destination. In this context, predecessor goods like horses and railroads have several disadvantages. Horses are expensive (notably in land), slow, and very dirty, albeit very flexible in providing service between any two desired points. In contrast, railroads are relatively fast, comfortable for longer trips, quite inflexible, and only cost effective when many people desire to make the same journey at the same time. Automobiles combined the low costs and speed of their machine-powered predecessors and the flexibility of their muscle-powered predecessors with by-products (emissions) that seemed to present far fewer problems of health and cleanup expense than did animal waste. This previously unavailable combination of features explains why motor transport was perceived to have such a high value and had such far-reaching indirect consequences.

Clearly, the automobile has been one of the greatest forces for freedom in the whole of human history. It has made affordable to hundreds of millions, and soon billions, of people some of the things that human beings crave the most: autonomy, mobility, and a greater choice about where to live and whom to have as neighbors. As every country in every region of the globe reaches the level of development currently represented by Thailand or Malaysia, the first thing desired by virtually every household is a car.

The attribute described above as "flexibility" explains why the mobility provided by the automobile is so valuable. Cars owned by individual households save time in contrast to common carriers like the bus, train, or airplane. When passengers are "batched" together into large units per departure, there is inevitably an increased waiting time for the next departure for a given destination, and some passengers will leave at a departure time different from the one they originally desired. The increased destination flexibility of the automobile permits a more spread out pattern of residential land use, which in turn fosters privacy and freedom. The value of the suburban single-family house to its inhabitants emerges, at least in part, from the decline in the COL created by the invention and development of the automobile.

Quality Improvements in Existing Products

If a new industry is sufficiently important, demand for improvements in its product will call forth more inventions that lead to a stream of new goods. The early automobile was hard (and dangerous!) to start, cost an arm and a leg, had a rough ride, broke down frequently, and offered little protection from the elements. A series of improvements in a wide variety of components led to automobiles which provided far more value to users. Similarly, early computers were large, slow, required years of training to use, consumed vast amounts of power, failed frequently, and could not store programs or databases large

enough to solve many common problems. Improvements in a wide variety of underlying technologies, from photolithography to software engineering, have permitted the development of computers that are vastly superior in all these dimensions.

Health Improvements

When we think about increases in social welfare over time, we focus on objective human needs that were first satisfied by one or more new goods. As we have seen, the long-standing desire for mobility and flexibility was satisfied by the automobile and the complementary capital and services (e.g., highways and service stations) that grew up to support it. Similarly, people have always had headaches and have always been in danger of death from infection. Aspirin and penicillin solved these problems and clearly increased human welfare. Any invention or discovery of new goods of this type raises the ability of the productive sector to meet human needs. The costs of achieving any given level of well-being (the true COL index) fall dramatically when modest expenditures can save previously unsavable lives or assuage previously unavoidable pain. Life expectancies have increased by about one-half during this century. Much of the credit for this tremendous improvement in human welfare goes to public health improvements interacting with technological advances in the medical and pharmaceutical industries.

The founding of new industries and the creation of new goods have promoted freedom and mobility, lengthened lives, virtually eliminated household drudgery, provided new conveniences, created previously unimaginable worlds of entertainment, saved time, and made a wide variety of human wants easier to satisfy. Any previously unmeasured decline in the true COL in comparison with the CPI has as its counterpart a large previously unmeasured increase in real wages. Today's workers obtain more services of greater value in return for less time spent at work and less time spent at household production.

Complementarities

We have already indicated that the full diffusion of a new good may require a host of supplementary inventions and innovations, such as highways and service stations in the case of the automobile. New goods are seen as inputs into economic processes such as household production. Combined with other inputs, some new themselves, the new goods produce useful services. There are at least three different types of complements to new goods. First, there are market-supplied complements: gasoline for automobiles, software for computers, or programs for television. Second, there are public or external complements: roads, the Internet, or the electromagnetic spectrum in the three examples above. Finally, there is information capital or changes in practices that come from using the new goods: consider the driver at the wheel, the travel agent at the computer screen, or the parents sleeping while their children watch

cartoons. All of these complementary relationships are part of the process by which new goods are integrated into the fabric of everyday life.

The absence of the complement when the new good is first introduced may slow the rate at which it produces social gain. Individual consumers or businesses examining the new good may find it initially unattractive because of the absence of crucial complements. Creating the complements is often itself as technological an activity as creating the new good (Bresnahan and Trajtenberg 1995) and thus subject to the problems of incentives for innovation. The pace of creation of potential social gains from the new good is then determined by the pace of invention of complements. As the literature on the diffusion of new technologies emphasizes, the process of adaptation may proceed far more slowly than the process of invention. The pace then depends on the cost and difficulty perceived by the adapter in making complementary changes.

Yet complementarities have another side, which is leverage. New goods which establish a system or platform for complements can set off a train of complementary innovation. Thus the invention of computer hardware has led to generations of software development. The motion picture camera and projector have led to the production of thousands of films. Record, cassette, and compact-disc players have led to a vast multitude of sound recordings and a huge increase in the demand for performing artists. This leverage is a powerful force for creating a wide variety of new follow-on products. Typically, these are in the relationship of hardware to software. The leverage comes from a variety of uses or contents delivered over a general and reusable system.

Complementarities and Consumer's Surplus

The existence of complementarities to new goods leads to two other conceptual areas. Suppose that automobiles are only valuable with gasoline and roads, and that to achieve the full social value of automobiles we need to reorganize urban and suburban land use. Since many of those things in fact occurred, we might draw figure 1. In the figure, we draw two demand curves, D_0 and D_1. D_0 represents the demand for automobiles before the complementary investments have been made, and D_1, the demand curve afterward. Clearly D_1 will be farther from the origin as long as the introduction of complements increases the demand for automobiles.

In figure 1 we have also drawn the consumer's surplus that would be gained by lowering the price of automobiles from its initial value to the level represented by the horizontal line. Note that the social value of the invention of the automobile is conditional on the existence of the complements. The "before" consumer's surplus is smaller because automobiles are hard to use if gasoline cannot be purchased readily, and because without supermarkets or suburban houses automobiles confer fewer benefits. The large "after" consumer's surplus triangle is at least in part the result of investing in the complements as well as inventing and improving the automobile.

While figure 1 shows a large consumer's surplus triangle associated with

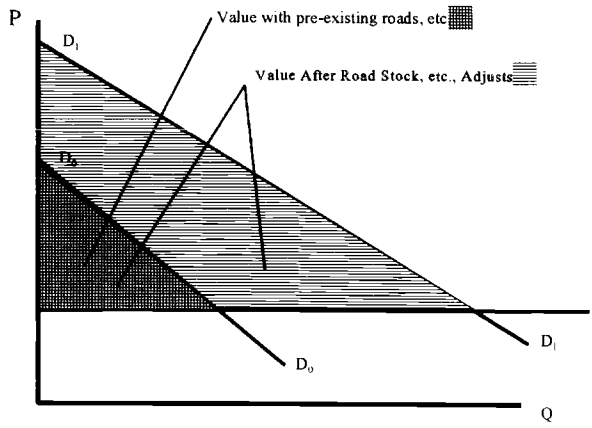

Fig. 1 Value of cars with and without complements

complementary investments, the distinction may be exaggerated from the perspective of today's consumer. The process of investing in the new good and its complements brought with it a whole new set of habits, tastes, and knowledge; eliminating the automobile would apparently leave us very badly off. Yet were our grandparents that badly off? They did not have the modern tastes and habits; they lived in communities where shopping was within walking distance at a time when walking down the street brought its own benefits of greetings from neighbors and of close social contact.

This distinction is closely related to the traditional concerns of index number theory. It is well known that a consumer price index based on the Laspeyres formula (i.e., using the expenditure weights of the first year of an interval of, say, a decade) exaggerates the true change in the COL by ignoring shifts in the expenditure patterns of consumers in response to changes in relative prices. In the classic example, using initial weights for expenditures on beef and chicken exaggerates the increase in the COL when the relative price of beef increases and consumers shift toward chicken. And in parallel, the use of a Paasche formula (i.e, using the expenditure weights of the last year of the interval) understates the true change of the COL.

In the same way, assessing the value of an invention like the automobile from today's perspective, with its highly dispersed suburbs, jobs, and other aspects of land use, surely overstates the value of automobiles as a new good. The favorable aspects of denser neighborhoods cited above may simply be unfamiliar to today's suburban residents, who therefore place no value on them. Similarly, the old-fashioned general store may have charged higher prices than succeeding forms of retailing like the supermarket, but it provided a community center, information, and gossip that many lonely individuals would value today if they knew where to find them.

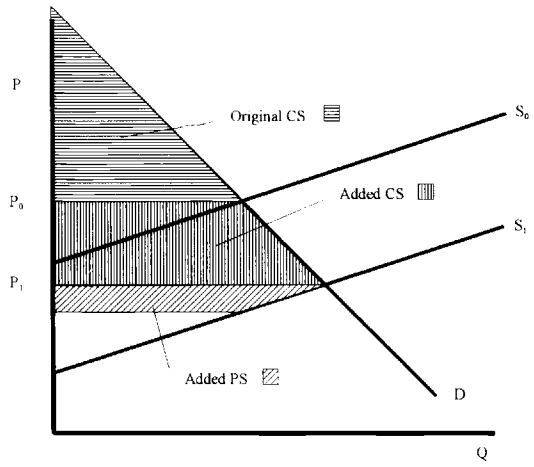

Fig. 2 Effects of a supply shift

Price Measurement and Consumer Value

Our introduction of the consumer's surplus triangles in figure 1 suggests a way of illustrating how intimately the measurement of changes in the true COL is related to the concept of consumer's surplus (or value). Let us consider a new good that reduces the cost of an hour of viewing recent movies, namely the VCR. The invention is represented in figure 2 by a downward shift in the supply curve for "entertainment services" from S_0 to S_1. The demand curve D is unchanged, since we assume no change in income, tastes, or the prices of other related goods. The market for entertainment services shifts from an equilibrium with price P_0 to one with larger quantity and lower price, P_1.

However, the true change in the cost of making the services is measured by the vertical downward shift in the supply curve S_0 to S_1, not the observed difference in price ($P_0 - P_1$). These two concepts differ because of the upward-sloping supply curve. The job of the official price measurement agency is to measure the marginal cost of an increase in output, so that the true change in cost can be disentangled from the observed change in price. At present this task is not adequately carried out by the statistical agencies in most countries, except in special cases, including that of automobiles in the United States where a considerable effort is made to obtain from manufacturers an estimate of the added cost of new equipment. The hedonic price technique is an alternative method that uses statistical regression to obtain an estimate of the added price (and implicitly cost) contributed by an extra quantity of an output "characteristic" (e.g., speed and memory size for a personal computer); in figure 2 this is analogous to measuring the slope of the supply curve S_1.

In figure 2, consumer's surplus prior to the invention is the triangle labeled "Original CS." The invention adds the "Added CS" area. The remaining area,

labeled "Added PS," represents the increase in producer's surplus associated with the invention. Thus, the one-dimensional representation of the decline in price corresponds to a two-dimensional gain received by consumers and producers together.

Distinguishing New Goods from New Varieties of Existing Goods

Thus far we have emphasized the long-run impact of major new goods. But not every trivial difference between one good and another warrants the label "new good." We know that consumers exhibit strong tastes for certain goods as a result of fads, fashion, and the influence of advertising (which may simultaneously serve as a valuable conduit of information and as an influence on consumer tastes for particular products and brand names). How can we distinguish between the "fad and fashion" type of consumer preference and the preferences revealed by the "objective unmet needs" criterion that we have previously employed to identify genuinely new goods?

The Taste for Variety

A central theme of this section is that we cannot always trust consumer behavior to reveal the true value of goods and services. To see this, consider "low hemlines" as a new good. We see consumers switching to low hemlines, refusing to treat low hemlines as a perfect substitute for higher ones. Are we then correct in calculating a consumer's surplus associated with low hemlines as a new good? A few years later, we would be forced by this precedent to treat high hemlines as a new good creating consumer's surplus. Obviously, an error has been made. The error lies in modeling this as a stable taste for variety. Each time, the demand for the switch to the other length is a demand for novelty, not for variety. To complete the welfare calculation, we would need to "age" the older product type, that is, to remove surplus from it because it had become nonnovel. The switch would then be explained as escaping from the old, and we would correctly conclude that welfare has remained constant over time. A complementary way to approach this problem is to admit that anything novel is inherently subject to depreciation. Below we return to the role of depreciation in assessing the gains from new goods.

Welfare Gains within Product Categories

Is acetaminophen as much a new good as aspirin? If we continue to use the ability to satisfy objective previously unmet human needs as our criterion for assigning the terminology "new good" to a new product, we would stress the advantages of acetaminophen over aspirin: some people are allergic to aspirin, many people's stomachs are irritated by it, and so on. Similarly, a dramatic expansion in the number and kind of antibiotics offers physicians the opportunity to avoid adverse side effects and to deal with bacteria resistant to penicillin (the first antibiotic). The increasing variety of both painkillers and antibiotics,

arising from an ongoing process of new-goods introductions, allow the product category "pharmaceuticals" to meet objective human needs in an ever more satisfactory way. Thus we distinguish between new goods which open up whole new product categories and other new goods which increase quality or variety within product categories. As long as there are diminishing returns to quality and variety, new goods that establish entire new categories (like the automobile) will be economically more important than improvements that occur within categories.[2]

The last observation calls for methodologies that measure the economic importance of new goods. By how much *has* the true COL been lowered by the invention of aspirin? by the further development of acetaminophen? As with all COL-measurement approaches, the authors in this volume use demand-based assessments of willingness to pay. The effort is to assess the amount by which consumers would have to be compensated for their headaches if aspirin (or acetaminophen but not aspirin) were prohibitively expensive. The wide variety of available measurement tools—price indexes, hedonic price indexes, and demand-system measurement—are all attempts to make this assessment. All use demand behavior to reveal value in use.

For consumer goods, the objective unmet needs approach to defining new goods has limitations. If we return to the example of painkillers, we note that many of the new products in this category are (it seems) trivial recombinations of existing ingredients. With some marketing magic, however, they nonetheless sometimes succeed in gaining substantial market share. A research approach which seeks to name the previously unmet need will be likely to fail. Indeed, many analysts are tempted to conclude that the value of these new varieties is basically zero. Implicitly or explicitly, they find that the consumers who switch to these new varieties are making a mistake. At least in this example, there seems to be blatant contradiction between the "objective unmet needs" approach and the actual behavior of consumers.

Many of the same analytical problems arise throughout the consumer goods economy where advertising, marketing, and, more generally, image matter a great deal. Is the motion picture *Rocky IV* a new good? Is its relationship to *Rocky* to be understood as embodying diminishing returns in the same way as the relationship of tetracycline to penicillin? The importance of image, reputation, and marketability suggests that the two relationships are fundamentally different.

Marginal Value versus Inframarginal Value

In evaluating the latest new goods from Hollywood, it is important not to fall into errors associated with the diamond/water paradox. We may find that many current motion pictures or music albums are tawdry or cheap. Dramatic

2. The literature on product quality and product variety contains a great deal of analysis of the extent of diminishing returns. See Eaton and Lipsey (1989).

declines in the costs of making and disseminating entertainment products are the result of many new types of high-tech equipment used in the entertainment and communications industries, and of such new household goods as the radio, record player, cassette player, compact-disc player, and VCR. This lower cost of producing entertainment services, as in figure 2, naturally leads to a lowered threshold for introducing a new motion picture or album. That the marginal entertainment product is, well, marginal, does not show that there is no contribution to economic welfare from the totality of new entertainment products. Stated another way, inframarginal consumers receive a huge gain in consumer's surplus from the lower quality-adjusted price of entertainment.

Similarly, our great-grandparents would probably find most modern uses of such basic commodities as light or clean water extremely wasteful. These commodities are so much cheaper than they were a few generations ago that rational consumers put the marginal lumen and liter to much lower-value uses. The total contribution of the new goods in permitting this "waste" is not to be discounted, however. Many inframarginal uses are far more valuable than those at the margin, and again the gain in consumer's surplus can be enormous.

Current controversies over the wasteful use of water and energy should remind us that the perspective of stable preferences is not always the right approach. Between different people now, and within the same group over time, values, tastes, knowledge, and assumptions about the world may all change in response to changing relative prices made possible by technological advances. The very process of long-term economic growth, and especially of changes in style of life and work, contributes to these changes in values, tastes, knowledge, and assumptions. As a result, to assume that tastes remain fixed over a long period of time—decades or centuries—is surely an analytical error.

The Measurement of Value

The economic importance of new goods ultimately lies in their contributions to consumer welfare. Measuring that contribution reliably is therefore an important aspect of constructing a true COL index. Since much technical progress in modern societies is embedded in new goods, any quantitative assessment of long-run economic success also calls for these measures.

Measuring the Novelty of New Goods

Does a new good provide fundamentally different value to a user, or can it be viewed as embodying different quantities of particular "characteristics" that already existed? The first antibiotic might be viewed as a fundamentally new good, since the characteristics of having bacteria-killing capabilities did not exist in previous drugs. In contrast, an electronic calculator might be viewed as a "repackaging" of characteristics previously embodied in slide rules and rotary-electric calculating machines. This distinction between fundamental novelty and repackaging brings together some of the basic modeling and mea-

surement questions that lie at the heart of this book. Should we think of the automobile as just another transportation mode with somewhat different characteristics than the railroad or horse and buggy?

There are advantages to taking this view. One can think of the underlying consumer need of fast, flexible transportation as being fundamental. The costs of meeting that need fell with the introduction and development of the automobile. The researcher's task is to quantify the extent of that fall in cost, which can be represented by the downward shift between supply curves S_0 and S_1 in figure 2 above. This task is not trivial, for it involves thinking through such diverse issues as the availability of gasoline and roads, the crankiness of early starters, and the external (unpriced) cost of streets previously made filthy by horse droppings. Having solved those problems, however, the researcher has the somewhat easier task of putting the new good in overall context. A particular need was badly met and now is better met. A useful quantification of *how much* better is the carefully researched total social cost of meeting the need. This is the characteristics approach of Lancaster (1979) or the household production function approach of Becker (1965).

An alternative view stresses the differences rather than the similarities of the new good. Automobiles and horses, or automobiles and railroads, are such poor substitutes that we should think of a new item in the utility function—automobile services. Raff and Trajtenberg discuss this distinction in their paper on the early automobile industry (chap. 2 in this volume). They note that some new automobiles have "new item in the utility function" features, for example, those that embody dramatic changes in product characteristics. Others seem instead to offer cheaper versions of existing characteristics. Raff and Trajtenberg link this distinction about the economic role of the new vehicle to the difference between product and process innovation. At its most valuable, product innovation adds new items to the utility function, rather than lowering the prices of existing goods. In contrast, process innovation reduces the cost of existing goods.

One can probably take either side of this debate on any of a wide variety of groundbreaking new goods. The radio receiver can be thought of as a wholly new good or, together with the broadcast, as a combination of a more rapidly delivered newspaper, a more versatile player piano, and a cheaper, though lower sound quality, concert hall. The computer can be thought of as a revolutionary invention or as a much cheaper calculator, bookkeeper's binder, and typewriter rolled into one. This volume contains interesting examples of each approach, both of which have their strengths and weaknesses.

At the other extreme, we can probably assume that an incremental automobile product—say a light blue rather than a dark blue 1995 Ford Escort—has a single product demand curve well approximated by the horizontal line $dd(-\infty)$ in figure 3. That is, the light blue and dark blue models are perfect substitutes. If the light blue model were priced one hundred dollars more than the dark blue model (and otherwise identical models in other colors), it would sell very few, if any, units.

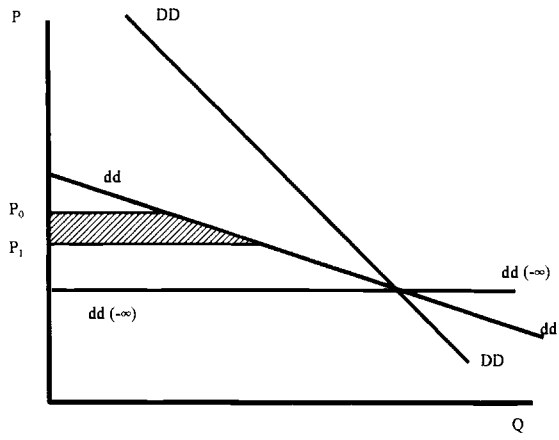

Fig. 3 Consumers' gain from lowering one product's price

Hedonics and Welfare

A closely related issue is the difference between hedonic pricing and the extent of the COL reduction associated with a new good. Hedonic pricing reports the change in quality-adjusted prices for goods that are changing in quality. If newly introduced goods are nearly perfect substitutes (after quality adjustment) for existing products, linking them into a hedonic index will capture their value. That near perfect substitution goes under at least three alternative names: (1) "repackaging," (2) high substitution elasticities across products, and (3) the absence of market power for single sellers. However, if the new goods are close but not nearly perfect substitutes for existing ones, hedonic pricing will miss part of the COL reduction associated with the new good.

Recently, Trajtenberg (1989) has offered an analysis of these intermediate cases. One ingredient in his theory is a product's uniqueness, determined by its distance from other products in the product space. The farther any particular product is from others, the more it tends to have product-specific demand curves like *dd* and not $dd(-\infty)$. Examples are products which extend the product space or which fill in important gaps in the product space. Such new products will (1) have economic value through product-specific consumer's surplus, not just by lowering the hedonic price line for the whole industry, (2) have moderate substitution elasticities with other products, and (3) provide some market power for sellers.

In figure 3 we offer a simple illustration of this point. In it we quality-adjust the prices of all goods in the same market so that they may all be shown along the same vertical axis. For convenience in graphing we assume that at the same quality-adjusted prices all the goods sell the same quantity, although this assumption is irrelevant. In figure 3, the demand curve labeled *DD* shows how the demand for a typical single good changes when the prices of all goods in the market are altered together. *DD* has slope because it is a market, not a

single-product, demand curve. We also show two alternative single-product demand curves. The one labeled $dd(-\infty)$ is horizontal and corresponds to products that are perfect substitutes. When products are perfect substitutes, any seller raising the price of its product above other sellers' prices instantly experiences a decline in its demand to zero. There is no area under demand curve $dd(-\infty)$: removing a product from the marketplace, leaving the price of perfect (quality-adjusted) substitutes in place, does not lower welfare.

By contrast, the alternative single-product demand curve labeled *dd* is sloped. This corresponds to the case of close but not perfect substitutes. A reduction in the price of this product from P_0 to P_1 increases consumer welfare. Ignoring income effects, the increase in welfare is the consumer's surplus, the shaded area under *dd* between P_0 and P_1.

Following from the important contribution by Trajtenberg, two of the papers in this volume attempt a calculation of this sort: Hausman's paper on cereals and Greenstein's paper on computers. This measurement exercise is difficult because the slope of *dd* depends on the degree to which preexisting goods are (after quality adjustment) substitutes for the new good.

The Depletion Hypothesis, Diminishing Returns, and Other Qualifications

In most advanced industrial countries, the growth rate of productivity slowed significantly in the past two decades in contrast to the half century prior to 1973. This much-discussed "productivity slowdown" was addressed by Nordhaus (1982) who proposed his "depletion hypothesis." The world is running out of new ideas just as Texas has run out of oil. Most new goods now, compared with those of a century ago, are not founding whole new product categories or meeting whole new classes of needs. Is it merely a coincidence that the period of most rapid productivity growth in U.S. history corresponded to the interval between roughly 1920 and 1965, when such fundamental inventions as motor cars, airplanes, electric machines, light, appliances, radio and television, chemicals, plastics, antibiotics, together with their complementary and subsidiary inventions, were spreading through the country? Slow productivity growth since the early 1970s may be a result of diminishing returns, which in our framework can be interpreted as a predominance of innovations that take the form of repackaging rather than the introduction of truly new products.

Diminishing Returns: Too Much Complexity, Variety?

Surely, some might respond, the ever spreading personal computer and its associated software have created a revolution as profound as the great inventions of the late nineteenth and early twentieth centuries. But there is room for doubt. It is hard to find much evidence of productivity growth created by personal computers (see Baily and Gordon 1988). Much of the increase in the

output of computers captured by the official computer price index (based on the hedonic technique) measures increases in speed and memory size that are consumed by the requirements of ever more complex software. The benefits to the average user of marginal refinements in software sophistication and graphical interfaces are minor compared to the benefits of the invention of the original spreadsheet and word processing software. Many computer users and administrators are dismayed by the current cycle of upgrades and obsolescence with its attendant need to buy new hardware, install new programs, and retrain staff, all in the name of benefits that provide dubious value.

Along the same line, modern innovations may be coming up against inherent limits in the availability of time and the size of the human "stomach." Some inventions in the home entertainment industry, such as the replacement of the cassette player by the compact-disc player, provide alternative uses of a fixed amount of time with a marginal improvement in the quality of that time. Supermarkets are crammed with new food products, but each new product replaces the "stomach space" previously available for older products. Has the level of satisfaction actually increased, or do we have here another example of illusory benefits created by marketing and advertising? Those taking this approach would view with some skepticism the benefits of the development of Apple-Cinnamon Cheerios estimated by Hausman in this volume.

Negative Developments in Modern Society

We have already stressed that new inventions breed changes in tastes. Today's suburbanite places a higher value on the automobile, out of necessity, than a resident of a dense community in the late nineteenth century where home and work were close together and where nearby shops provided information services for which today's resident is dependent on electronic media. If we could transport the family of 1895 to today, it might marvel at many inventions but lament the passing of some of its favorite pastimes, including the dance hall, player piano, and burlesque.

The danger of exaggerating the importance of new goods comes not just from the change in tastes over time, but also from developments that are objectively negative from the perspective of either 1895 or 1995. Not just crime but the fear of crime has increased greatly in most areas of the country, leading to expenditures on guards, security systems, and even walled-in communities with security checkpoints. The investment in "security services" increases the gross domestic product without causing a corresponding increase in consumer welfare.

We refrain from placing environmental pollution on the list of modern negatives, because pollution in most American cities has been greatly reduced since World War II, primarily by a shift from coal to natural gas for heating but also by a series of government regulations that have added devices to automobiles, electric generating stations, steel mills, and other facilities, and have measurably cleaned up the air. Pollution surely got worse between the dawn of the

industrial revolution and some point in the twentieth century, but then this process was reversed by the benign development of facilities for the widespread distribution of natural gas together with compulsion from government regulations.

This introduction has emphasized the many dimensions in which new goods improve economic welfare and the reasons much of this improvement in economic well-being has been omitted from official statistics that measure economic progress. This section has introduced three types of qualifications. First, the pace of introduction of truly new goods, contrasted with "repackaging" innovations, may have slowed down. Second, our tendency to place a value on new goods from our modern perspective introduces a classic index number problem, since new goods may appear to be less valuable to hypothetical observers from a century ago with different values and tastes for community, mobility, and adventure. Finally, some new developments are objectively negative, including crime and pollution.

Our summaries of the papers in this volume are grouped into three categories: "Historical Reassessments of Economic Progress," "Contemporary Product Studies," and "Measurement Practice in Official Price Indexes." In discussing the major findings of these papers, we will return to many of the themes advanced so far and point to links between the papers and our previous analysis. Could the qualifications introduced in this last section qualify in a substantial way our presumption that official statistics have substantially understated the rate of economic growth? The dramatic findings of our first paper on the history of light force us to confront this issue head on.

The Papers in This Volume

Historical Reassessments of Economic Progress

The lead paper in the volume is by William D. Nordhaus. This highly original paper breaks new ground by creating a quantitative history of light from the open fire of cave dwellers to the modern compact fluorescent lamp. Data are developed for the whole historical range of lighting devices, including data on light output in lumens and on energy consumption in Btus, allowing the calculation of improvements in lighting efficiency through time. Today's compact fluorescent lamp produces a ratio of lumen-hours per thousand Btu that is thirty thousand times higher than the cave dwellers' open fire. Over the shorter period since 1800, the nominal price of light in 1992 is estimated to have fallen to one three-hundredth of its value in the year 1800. By Nordhaus's calculation, the nominal price of light declined by 3.6 per year over the past two hundred years relative to a hypothetical alternative price index based on the price of energy inputs.

The Nordhaus paper illustrates the importance of framing an analysis of new goods in terms of the characteristics they produce (lumens) rather than the

goods themselves (whale-oil lamps, electric bulbs). By pricing the characteristic itself, Nordhaus is able to leap across history, linking successive products without missing the consumer's surplus created by, say, the switch from gas to electricity. His paper shows that it is possible to extend the characteristics approach beyond its previous use in defining computer output in terms of two primary characteristics, speed and memory.

Nordhaus enters more speculative territory when he extrapolates from his new evidence on the price of light to consider the magnitude of possible bias in historical data on the aggregate price level and the aggregate real wage. This involves speculating about the annual rate of bias for goods and services classified into three groups, ranging from traditional unchanging goods like food consumed at home to goods like transportation, home entertainment, and medical care that have experienced an enormous amount of technological change. In contrast to official data showing that real wages increased by a factor of 13 from 1800 to 1992, Nordhaus's "low-bias" estimate is for an increase by a factor of 40 and his "high-bias" estimate is by a factor of 190. As shown by discussant Charles Hulten, disposable personal income per capita in the United States in 1991 was approximately $17, 200, and thus 1800 real disposable income in 1991 dollars would be $1,300 by the official estimate, $430 by the low-bias estimate, and $90 by the high-bias estimate. The fact that these estimates strain credulity echoes several themes introduced above, including the need to evaluate changes over long periods not only from the perspective of end-of-period tastes but also from the perspective of beginning-of-period tastes, and the issue of diminishing returns to increases in such modern characteristics as lumens, computer speed, and automotive horsepower.

A new set of historical price indexes is also produced by Daniel M. G. Raff and Manuel Trajtenberg in chapter 2. This pioneering paper develops new data, hedonic price equations, and hedonic price indexes extending back to the dawn of the U.S. automobile industry in 1906. The basic result is that the real (CPI-adjusted) quality-adjusted price of automobiles declined at an average rate of roughly 5 percent per year from 1906 to 1940, thus halving every thirteen years. During the first decade of the interval prices fell even faster, reaching a rate about half as rapid as the rate of price decline reported in the best recent studies of the personal computer. This finding reinforces our previous emphasis on the product cycle, in which prices decline more rapidly in the early years of a product, and on the role of the product cycle in creating a significant bias in official price indexes when products are introduced late (the automobile was not introduced into the CPI until 1935).

Along the way, the authors discuss a number of fundamental issues involved in applying the hedonic methodology. One of these involves the absence of market-share data, since it would be highly desirable to weight the observations for the various models by their sales. To deal with this problem, the authors develop a separate hedonic index for low-priced Ford models and report that there is only a small divergence between the Ford index and their index

for the industry as a whole. Another important issue involves the treatment of individual characteristics which, while statistically significant, do not plausibly enter the consumer's utility function and lead to misleading hedonic price indexes when included in the regressions. Their discussion is part of a larger literature on the difficulty of applying the hedonic regression technique to a complex product like the automobile when several of the measurable characteristics (horsepower and especially weight) are ones that the consumer does not care about, while some that the consumer does care about ("ride" and "handling") may be difficult or impossible to measure.

In chapter 3 Walter Y. Oi provides a general analysis of the economics of inventions together with an application to a specific product, the air conditioner. Oi links the problem of defining a new product with that of defining a monopoly, where the operative issue is the lack of a close substitute. A new product is then one for which there is no close substitute available in the market, a definition that admittedly begs the question of what constitutes "close." The social value of an invention is measured, as in figure 2 above, by the sum of producer's and consumer's surpluses generated by the new product. Often this approach will understate the value of the higher quality of a new product like the jet plane, which not only reduced the real price of air travel but also was faster, safer, and quieter than its predecessors. In fact, Oi states that the social returns to a major invention like the telephone, penicillin, the computer, or air-conditioning "far exceed" the sum of consumer's and producer's surpluses by affecting third parties, changing preferences, and opening the way for technical advances in other sectors. The static approach also implies that some socially worthwhile inventions will remain uninvented ("in the womb") because in some cases the profits available to a monopolist inventor protected by the patent system do not cover the cost of the invention. Oi argues that unsuccessful inventions are not like dry holes in oil exploration, because there is no final product which can absorb the costs of the unsuccessful inventions.

Oi discusses numerous other aspects of the general process of invention. The cost of invention is not exogenous; rather, research and development play a dual role, not only increasing the average cost of an innovation but also raising its probability of success and its ultimate value. Oi develops more fully the idea of the product life cycle that we have discussed above and relates it to the speed of adoption or diffusion of a new product. The lag between invention in the laboratory and introduction into the marketplace can be long and variable, exceeding twenty years for fifteen of fifty inventions cited by Oi.

The case study in Oi's paper concerns the air conditioner, the dissemination of which was subject to a long lag between the issuance of the fundamental patent in 1906, the first introduction into movie theaters in 1922, and the mass-market sale of room air conditioners in the early 1950s. Oi's analysis focuses on the air conditioner as a major factor in bringing about convergence of real wages and productivity in the southern and northern United States. He also

points to a variety of benefits and costs for households, ranging from better and longer sleep and a reduction in allergies to the disappearance of "front porch society of Dixie" as "more neighbors closed doors and windows." He also examines a wide variety of externalities in the framework of figure 1 above, including the role of air-conditioning in raising the value of land in Manhattan, reducing automobile accident rates, and reducing the price of textiles and cigars.

A very different type of new good is examined by Joel Mokyr and Rebecca Stein in chapter 4. The authors argue that much of the great decline in mortality in the four decades prior to World War I can be attributed to an invention—the discovery and successful diffusion of the germ theory of disease. The analysis is embedded in a model of household decision making within the household production framework developed by Becker and others. In this framework, households combine goods and services purchased on the market ("market goods") with their own time to produce the "final goods" that appear in the household's utility function. For instance, households combine a television set and time to produce the enjoyment of watching a television program. In this interpretation the germ theory of disease offered households a new technology for transforming market consumption and time into better health. As households came to understand the processes that caused disease, they reallocated a certain amount of expenditure toward goods like soap and clean water and changed personal habits, thus shifting the way market goods and time were combined in the household production function toward greater emphasis on hygiene and personal care.

Mokyr and Stein echo Oi's emphasis on the long lag between the invention of the germ theory, its acceptance by doctors, and finally its diffusion into the practice of the ordinary household. Some of the authors' evidence for the diffusion of the theory rests on the rise, despite price increases, in England's per capita consumption of soap, particularly after 1900. They also discuss the role of improvements in the preservation of milk, improvements in the feeding of infants, and the democratization of access to piped water. The paper raises an issue about the allocation of public resources in that it implies that the level of poverty mattered less than the way households used the limited resources they had. In contrast to those who view rising incomes as a prerequisite for reduced mortality, it implies that public health education can have a high payoff even in those less-developed countries where the rate of economic growth is slow.

Contemporary Product Studies

In chapter 5, Jerry A. Hausman expands the theory of the COL index to incorporate new goods. New goods may be used in standard formulas, providing that the "virtual price" assigned to the new good before it is introduced is the one that sets demand to zero. As an example of this analysis, Hausman

undertakes to estimate the virtual price for a single new good, Apple-Cinnamon Cheerios, and calculate the surplus resulting from its introduction.

As with many consumer-products industries, ready-to-eat breakfast cereals offer a complex web of substitution possibilities among individual products. The virtual price of any particular new variety can only be higher than prevailing prices if existing varieties are not very good substitutes for the new good. This leads to considerable estimation efforts in order to learn the relevant demand elasticities. Hausman's estimation framework permits different amounts of similarity among cereal varieties. The extrapolation down to zero quantity to calculate the virtual price is also treated in a very flexible way. This flexibility in econometric estimation is, at the present moment, responsible for a gap between one-time COL index calculations in research papers like this one and the production calculations done by the statistical agencies.

Hausman's estimates lead to the conclusion that the virtual price for Apple-Cinnamon Cheerios was approximately twice the prevailing market price after the entry of the product. As a result, the new-good consumer's surplus for its introduction was substantial. Assuming this experience to be representative of the many new-product introductions in the cereal market, Hausman provides a back-of-the-envelope calculation that the CPI for cereal may be overstated by as much as 25 percent.

Finally, Hausman examines imperfect-competition effects. Under perfectly competitive price-setting, we typically assume that the prices of all other products may be held constant in assessing the impact of a new good. With imperfect competition, however, the marginal revenue of substitute products may be shifted in a first-order way. Hausman uses the Apple-Cinnamon Cheerios entry example to show that these effects can be substantial.

In chapter 6 Robert C. Feenstra and Clinton R. Shiells examine a possible upward bias in import price indexes because of the omission of new product varieties. Rapid growth of imports into the U.S. from developing countries over the last several decades provides much of the impetus for this study. The suspected price index bias has direct effects on the measured value (in U.S. consumer's surplus) of this trade. It also has the indirect effect of contaminating estimates of import demand, possibly leading to too-high estimates of income elasticities and too-low estimates of price elasticities.

Feenstra and Shiells use an econometric procedure to correct import price indexes. They build an economic model of preference for variety. The model shows how the demand for a given firm's (or country's) products responds to increased variety. They then show how to correct price indexes for omitted varieties in a way that depends on observable share data and a few unknown parameters. The econometric estimation, performed for all U.S. imports (except petroleum) at the three-digit SITC (Standard International Trade Classification) level, provides the unknown parameter estimates which permit construction of the corrected price index.

In chapter 7, Ernst R. Berndt, Linda T. Bui, David H. Lucking-Reiley, and Glen L. Urban examine product-level demand for antiulcer medications. They concentrate particularly on marketing variables, an important part of the new-good commercialization process in prescription drug markets. The focus is on the determination of sales at the individual product and brand level. The analysis distinguishes between "industry-expanding" and "rivalrous" marketing efforts. They find a smaller industry-expanding effect when more marketers are competing. They also find that rivalrous marketing efforts depreciate much more rapidly than do industry-expanding ones. This investigation into the effects of marketing variables on demand serves as part of a discussion of the competition among drug inventors and producers to introduce new products. The raw technology of a drug, its ability to provide health benefits, can generate no consumer's surplus until the drug is prescribed and used. The marketing efforts studied here provide the information, and perhaps the persuasion, that cause use.

In drug competition, invention of new chemical entities takes a long time. A leading product, such as Tagamet in the antiulcer market studied here, has time to build up considerable first-mover advantages. Berndt et al. show how marketing efforts for the second drug entering the market, Zantac, were important in overcoming these first-mover advantages. The process of informing (physician) customers is important in competition as well as in realizing the consumer's surplus associated with new products.

In chapter 8 Shane M. Greenstein attempts to measure the economic benefits that technological innovation in the computing industry gave to buyers. Covering the period 1968–81, this paper distinguishes between the declining price of computing power and the extension of computing capabilities. Extensions were important throughout the 1970s as computers became capable of performing ever larger tasks. In Greenstein's framework, the computer capable of completing a previously infeasible task is a new good. If two smaller computers cannot perform the tasks a larger one (with the sum of their capacities) is programmed to do, invention of the larger one creates new surplus for buyers, which Greenstein sets out to measure.

Greenstein examines this issue in a vertical product-differentiation model: all computer users value the same index of computer performance, but some value it much more than others. It is the consumer's surplus of the high-performance valuers which will drive the calculation of the social value of extending the product range.

Greenstein finds substantial consumer's surplus of this type. Over and above the benefits of a continuing decline in the price-performance ratio, the extension of the product range provided as much as half of the consumer's surplus enjoyed by computer users in the 1970s. Further, the benefits of extension in the early years of computing arise from the technical benefits of the few dominant computer systems of that era, such as the IBM system 360 and system

370. Finally, it appears that the time lags before buyers achieve the benefits of a new extension are quite long, a finding in common with those of Oi and Mokyr-Stein.

Measurement Practice in Official Price Indexes

In chapter 9, Paul A. Armknecht, Walter F. Lane, and Kenneth J. Stewart review the methods currently used to deal with new products in the best-known official U.S. price index. They distinguish replacement items (new models of previously available items that replace old models), supplemental items (new brands of currently available goods that supplement rather than replace older brands or models), and entirely new items that do not fit within any established CPI item category. Regarding new products, the authors admit that the CPI has no method for comparing totally new products with older products. New products are introduced into the CPI through a process of "sample rotation" in which item and outlet samples are reselected each year for 20 percent of the geographic areas. Thus, on average, it takes five years for a new item to enter the CPI, and even longer for a totally new product type like the VCR, which was introduced into the CPI in 1987, about a decade after it began selling in volume. Month-to-month price changes of new products are included in the CPI only in the months and years subsequent to their introduction. In the month of transition both the old and the new item (or outlet) is priced and all of the price difference is treated as a quality difference. Thus, if the new items or outlets provide consumer satisfaction more efficiently, the CPI will miss that effect. This may have occurred in the shift to newer discount outlets or in the replacement of cassette and record players by compact-disc players.

Because the CPI does not have any procedure for placing a value on the price decline implicit in the introduction of new products, much of this paper concerns the treatment of replacement and supplemental items for existing products. Much of their discussion involves the substitution that is initiated by field agents when an item is discontinued. The field agent introduces a new or updated version if possible, and Bureau of Labor Statistics (BLS) commodity analysts determine the treatment of the newly substituted item. In some cases the new item is considered to be directly comparable, and any quality difference between the old and new item is missed. A problem is created for products like televisions, which often fall in price although their features have improved. Analysts treat the new model as comparable to capture this decline in price but miss the additional improvement in quality built into the new model. The opposite case is when a new model or item is judged to be of dissimilar quality to an old version. Then the weight applied to the model is applied to the average rate of change in the product category of which that model is a part. This method creates problems for classes of goods like automobiles which change little in price except when new models are introduced; recently, new methods have been introduced to distinguish price changes across model years from those within model years. The third treatment occurs when direct quality ad-

justments are made between old and new models. This has long been done for new cars and trucks, based on production-cost data supplied by manufacturers, and is now done for specific apparel-item groups using the hedonic regression method.

In chapter 10 Marshall B. Reinsdorf and Brent R. Moulton address a bias in the U.S. CPI which has become known as "formula bias." This results from a tendency for sellers' prices to exhibit mean reversion. Prices that are low tend to rise at a rate higher than average, often because items have been on sale and return to the regular price. Prices that are relatively high tend to decline, or at least rise at a rate lower than average, as competition takes effect. A Laspeyres component index gives a large weight to those sellers offering sale prices in the base period and tends to rise rapidly as the heavily weighted sale prices revert to their regular values.

It is known that this type of basis can be avoided through the use of geometric mean indexes. The authors calculate alternative geometric and Laspeyres-type component indexes for the same underlying price data for the period June 1992–June 1993 and reach two findings. First, the geometric mean component indexes almost always exhibit lower rates of price growth than the Laspeyres-type component indexes do. More important, the size of the difference between the two indexes varies substantially between classes of items. For fresh fruits and vegetables and apparel, the Laspeyres indexes showed rates of change 2 to 3 percentage points higher than the geometric mean indexes. For other expenditure categories, however, the differences tended to be smaller, in most cases less than 1 percent a year. Overall, the authors conclude that replacing the Laspeyres-type formula with geometric mean indexes would (for items other than shelter) reduce the inflation rate in the overall CPI by about 0.4 percent per year.

In chapter 10, Andrew Baldwin, Pierre Després, Alice Nakamura, and Masao Nakamura have concentrated on the introduction of new goods in the Industrial Product Price Index (IPPI) in Canada and the Domestic Wholesale Price Index (DWPI) in Japan. They find that many goods newly introduced into the PPI and WPI are not actually new but have been produced for a long time previously. Many of the new goods are simply modifications of deleted goods. As in the United States all of the price differential between deleted and "new" goods is treated as a quality differential.

Much of their focus for both countries is on the treatment of computers. In Canada starting around 1986 the U.S. hedonic price index for computers was used as a proxy for Canadian prices, but in 1990–91 Statistics Canada began to develop its own hedonic price indexes. The Bank of Japan introduced U.S.-made computers into its import price index as long ago as 1965 but first introduced Japanese-made computers into its domestic WPI in 1987. The hedonic regression method for computers was introduced with the 1990 revision of the WPI. This is desirable in itself but has the undesirable side effect of tending to exaggerate differences in the growth rate of computer prices from other prices,

as other goods are still priced by the matched-models method. Somewhat surprisingly, the authors find that, despite the delay in introducing computing equipment into the PPI for Canada and WPI for Japan, these omissions had small effects on the overall values of the Canadian and Japanese indexes. This occurred primarily because of the relatively small share of computers within the total of manufacturing output for the two countries.

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